MYCOLOGICAL SERIES.—BULLETIN No. I.

DEPARTMENT OF AGRICULTURE
MYSORE STATE

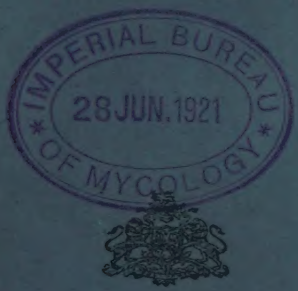
THE RING DISEASE OF POTATOES

(A PRELIMINARY REPORT)

BY

LESLIE C. COLEMAN, M.A., PH.D.

Mycologist and Entomologist to the Government of Mysore



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FOREWORD.

In accordance with orders issued by the Government of Mysore, the results of investigations conducted by the Agricultural Department will hereafter be published in the form of bulletins and not as heretofore in the annual reports of the Department. Each bulletin will deal with a single subject or with several closely related ones, and will be published as soon as the investigations have been completed or have reached a stage such that the results obtained are likely to be of practical value. This arrangement will, it is believed, make the results of investigations more readily accessible to those interested.

The following report on the Ring Disease of Potatoes is the first of these bulletins. As it has been written expressly for the information of those interested in potato cultivation in Mysore, an attempt has been made to deal with the subject in as simple a manner as possible. Scientific terms have therefore been carefully avoided. A comparatively large number of illustrations has also been prepared to accompany the text, as it was believed that by means of these the matters under discussion could be presented more clearly than by means of long descriptions. This fact accounts also for the comparative shortness of the text. A Kanarese translation of this bulletin is being prepared and will be available shortly.

It is intended to deal with this subject at a later date, at greater length and in a more scientific manner.

Leslie C. Coleman,
Mycologist and Entomologist.

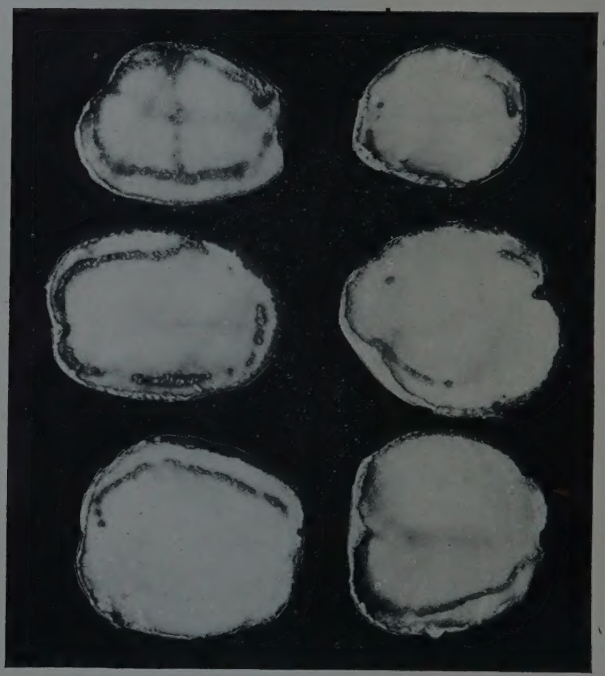

Fig. I.

Potato tubers showing early stages of the Ring Disease. The ring is complete in only one case. The tubers have been cut across, and the cut surfaces are shown in the illustration.

THE RING DISEASE OF POTATOES.

(A Preliminary Report.)

THE *Bangadi* or Ring Disease of Potatoes has been reported from various different localities in India. It was apparently first noticed in Bombay Presidency in the vicinity of Poona and later in other parts of the Presidency. Mr. Mollison, the present Inspector-General of Agriculture for India, then Superintendent of Experimental Farms for Bombay Presidency, carried out some very interesting and valuable experiments with regard to it, the results of which are embodied in two reports of the Director of Land Records and Agriculture for 1892-93. Dr. Butler has also noticed the disease in his paper on Potato Diseases in India (Agricultural Ledger, 1903, Vol. X, p. 85). He reports it as occurring or having occurred throughout Bombay Presidency, at Bangalore, in the Nilgiris and in Bengal.

With regard to the prevalence of this disease in Mysore, it is safe to say, from information already gathered by this office, that it is to be found in practically every locality where potatoes are grown. The extent of its ravages is certainly very much greater than is generally supposed. The Mysore potato-growers, it is true, know quite well the appearance of diseased tubers and appear to be, as a rule, careful to discard all such when seed is being prepared for planting. However, as they do not know the real cause of the disease or the manner of its spread, very many, if not most, of the diseased plants actually occurring in a field are put down as due either simply to "bad" seed potatoes or to "sourness of the soil," and are not referred to the real cause, the ring disease.

The disease is readily to be recognised by the sudden wilting of the potato plants in an affected field. By

wilting is meant the hanging down loosely of the leaves just as they do when the stem bearing them is cut from the roots. Usually one or two leaves first show the wilting, but within a few days the whole plant wilts down and dries up. If the tubers of an affected plant are cut through, some of them will almost certainly show a brown ring a short distance in from the surface. This ring will be found, usually at least, to begin at the point where the tuber is attached to the underground stalk which bears it and to spread from that point around to the other end of the potato. In its first stages, therefore, the ring is not complete but is rather simply indicated by a more or less distinct brownish streak in the neighbourhood of the point of attachment of the tuber. Such early or imperfect rings are indicated in Fig. I. The fact that the brown color appears first at the point of attachment of the tuber indicates that the disease has entered at this point from the stem into the tuber. If a diseased potato be cut and squeezed slightly, a series of small creamy-white slimy drops are to be seen exuding along the course of the brown ring. Such a drop, if examined under the microscope, is found to contain myriads of bacteria shaped like small and very short rods. (See Fig. II.) If a very thin slice of such a potato is examined microscopically these tiny rods are found chiefly in the vessels of the tuber which they plug quite full. These vessels are more or less tube-like structures which help to transport the sap and food materials from one part of the plant to another. In the tuber they form a ring just a short distance in from the outer surface, and it is in this ring of vessels that the disease first makes its appearance. From it the disease spreads to the rest of the potato so that, gradually, the whole potato is changed into a rotten mass. Other bacteria and different kinds of fungi aid in the destruction, so that an examination of such advanced stages of the disease would scarcely enable us to make even a conjecture as to which form was the real cause. Such advanced stages are represented in Fig. III.

It is quite clear and it is also quite well known to the potato-growers in Mysore that potato tubers affected by this disease will not keep well on being stored. As a

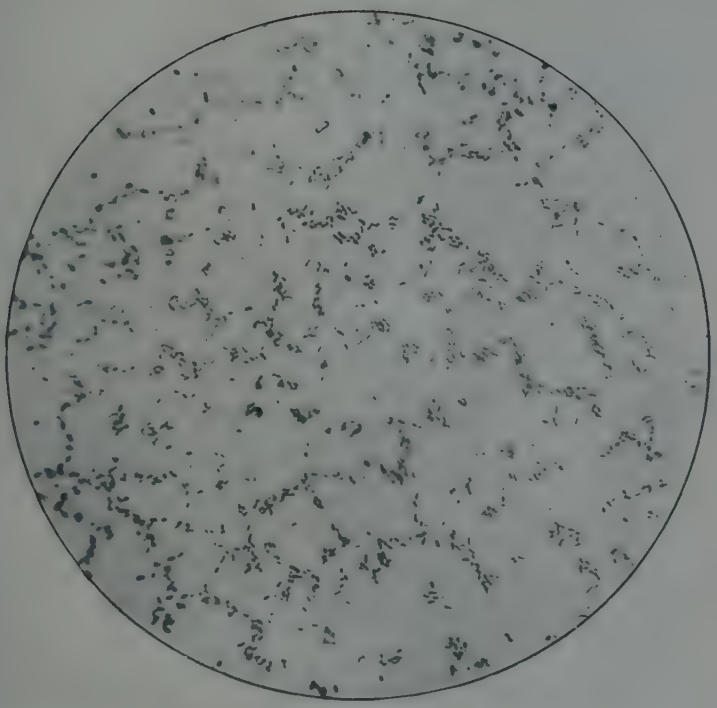

Fig. II.

Bacteria causing the ring disease of potatoes. These are taken from a pure culture or growth, and are enlarged in the picture over 2,000 times. The short rod-shape of the individual bacteria is clearly shown in the figure in those parts where they are well isolated from each other.

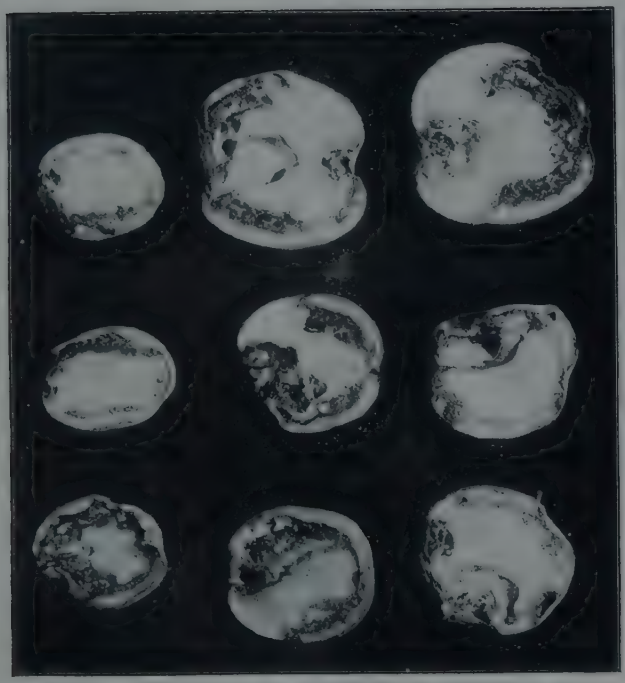

Fig. III.

Potato tubers showing advanced stage of Ring Disease. Even here the diseased rings are not in every case perfect, but the decay has reached a much more advanced stage than that illustrated in Fig. I.

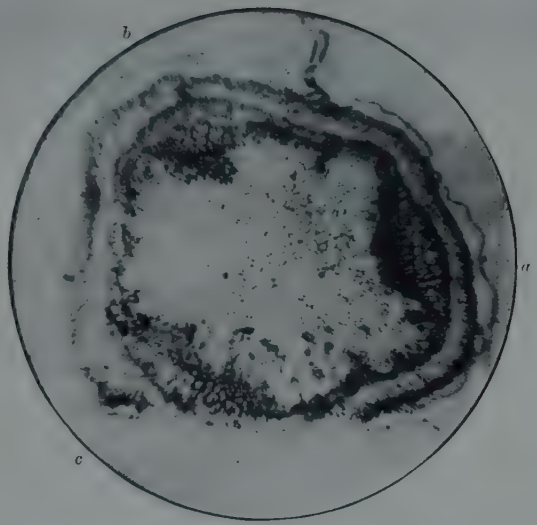

Fig. IV.

Section of healthy potato-stem enlarged about ten times. In the centre is the pith; just external to this is the ring containing the vessels. The vessels are in three groups, one (*a*) to the right and two (*b* and *c*) to the left in the picture. They are seen to be quite open and unobstructed. (Compare with Fig. V.)

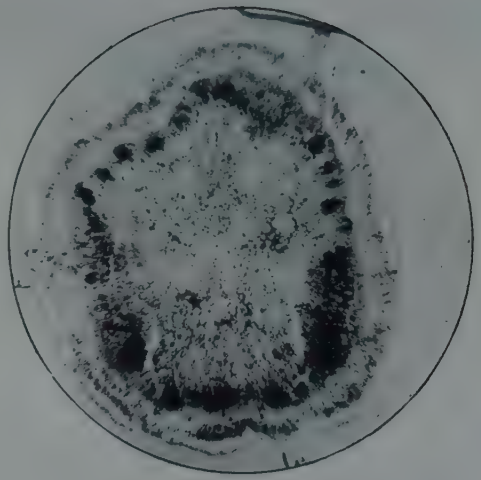

Fig. V.

Section of diseased potato-stem to be compared with Fig. IV. The black areas in the ring show the regions where the vessels have become plugged with bacteria. A comparatively small number of vessels are seen to be still open. The vessels are not so markedly grouped as in Fig. IV, but are distributed more uniformly throughout the "ring."

matter of fact, they usually decay quite rapidly. Moreover, diseased potatoes when cooked have a bad flavour. Just what part of the loss which takes place in stored potatoes is due to this disease, cannot, of course, be estimated, but it is safe to say that very much of the rotting that occurs is really due to the presence of these bacteria in the potatoes already at the time of harvest.

Vessels, however, are of necessity also to be found in the roots and the stem and right out into the leaves. It is by means of them that food materials and water are carried from the roots up into the leaves. The potato stem when cut across and examined under the microscope is seen to possess a ring-like mass of harder and tougher substance lying about one-sixteenth inch in from the surface and itself surrounding a softer pith in the centre. In this harder ring lie the vessels mentioned. As these vessels run lengthwise to the stem, when the stem is cut across they are to be seen simply as more or less roundish openings embedded in a finer network. Fig. IV shows such a slice made across a stem and magnified about 10 times.* If now we examine the stem of a diseased plant we find here too that the vessels are plugged with masses of the bacteria. (See Fig. V.) If such a stem is cut across and squeezed at the cut surface slimy whitish drops similar to those found on the cut tuber will be seen; a healthy stem cut and thus squeezed gives out only a colorless, watery liquid with a number of air bubbles. We are now prepared to understand the cause of the wilting of the potato plant. The vessels which are formed to carry water, etc., from the roots up to the leaves are plugged with masses of bacteria so that they cannot perform their work properly. They are about as completely plugged as a water-pipe would be were it filled up with earth. As the leaves cannot get sufficient water they wilt. In very dry weather we have quite a similar wilting in plants, but then it is because there is not sufficient water in the soil. In the case of plants suffering from ring disease, although the soil may contain a supply of water much more than sufficient for the plants' needs, that water cannot reach the leaves and upper

* By this is meant that the picture represents the slice 10 times as broad as it really is. The picture is, therefore, really 100 times the size of the slice itself.

part of the stem because the vessels which should carry it are filled with these minute bacteria.

Fig. VI shows a small part of the slice of the stem shown in Fig. V very much more strongly enlarged. The whole of the part shown in this figure lies in the ring containing the vessels. These vessels are shown in the illustration as the larger openings in the network. Some of the vessels are seen to be quite plugged with bacteria and therefore appear quite black in the picture. In others the bacteria are not so closely packed and can be made out as small black dots. In still others the bacteria are to be seen only as a few black specks scattered through the whole opening.

Now that we have formed an idea of the nature and cause of the wilt we are prepared to proceed with the study of the disease.

The questions we have to investigate are:—

1. Are these minute bacteria the real cause of the disease?

2. If so, how do they get into the potato plants, and how do they increase to such numbers as to block up the vessels?

1. Are these bacteria the real cause of the disease?

The reasons for answering this in the affirmative are as follows:—

(1) They are to be found in large numbers in the vessels of every potato plant suffering from the disease.

(2) In the earlier stages of the disease they are the only organisms to be found in the vessels. Later, when the whole plant or tuber begins to rot, other bacteria, as well as certain kinds of higher fungi, are to be found associated with them.

(3) It has been proved by direct experiments that these bacteria are capable of causing the disease. These experiments were carried out as follows:—

The bacteria were removed from diseased potatoes and grown in the laboratory in such a way

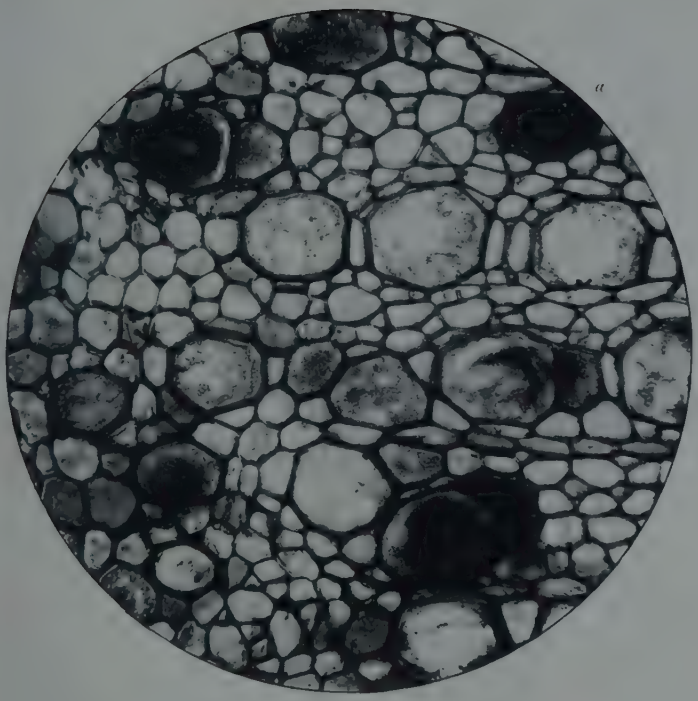

Fig. VI.

A small part of the diseased "ring" (shown in Fig. V), more highly magnified. The vessels can be readily made out, as the larger openings in the figure with thicker walls. At *a* is shown a vessel completely filled with bacteria. Beneath it are three vessels in a row, showing very few bacteria. Intermediate stages can be seen, here and there, throughout the figure. It should be noted that probably all the vessels here were filled with bacteria, but in making the section, in some cases the bacteria have fallen out.

A. B.

Fig. VII.

The potato plants in pot B, with one exception, inoculated by means of pure growths of the bacteria causing Ring Disease. The single uninoculated plant (to the extreme right) is still healthy; all the rest have wilted. Pot A contains uninoculated plants of the same age as those of pot B.

that they could be separated from all other forms of bacteria. When by careful testing it was found that we had masses of these bacteria growing quite free from any other form, such masses were used to give the disease to healthy potato plants. Small pricks were made in the leaves and leaf-stalks of healthy plants with a fine needle which had been held in a flame to kill off all bacteria that might be on it. Then masses of these bacteria were stroked over these pricks so that the bacteria could enter into the substance of the plant. After a few days it was noticed that the leaves and plants infected began to wilt and in the course of two to four weeks the plants were quite dead. (See Fig. VII.) Moreover, when the stems of these plants were cut across and examined under the microscope these same bacteria were found inside the vessels. Some of the tubers attached to these plants also showed the characteristic brown ring. We have thus shown clearly that these bacteria are the real cause of the ring disease of the potatoes.

The next question is, *Provided these minute bacteria have gained an entrance into a healthy plant, how do such minute things spread from the point where they entered, and grow in numbers so as to fill up practically all the vessels of the plant?* It must first of all be noted that although these bacteria are very minute they increase in number so rapidly that within a few days each one of them has increased to millions. Moreover, these small bacteria are able to swim about in the watery fluid in the vessels of the plants and can easily spread so as to occupy the vessels throughout the whole plant. In the case where the bacteria are artificially introduced into one of the leaves this spread of the bacteria can be readily followed. First the leaf which was infected wilts, then the leaf immediately above it or immediately below it on the same side of the stem and so on.

The question *How do these bacteria gain an entrance into the potato plant?* is a very important question and

much more difficult to answer. The results of experiments here as well as of those conducted by Mr. Mollison, Inspector-General of Agriculture, some years ago in Bombay, indicate that there are at least two common modes of infection. The first of these is through the sowing of seed which already has the disease. It seems quite reasonable that if a potato which already has these bacteria in its tissues be sown, one of two things is likely to happen.

Firstly, if the potato is very badly diseased it will probably rot in the ground without sprouting at all. If, however, it is not so badly diseased it will sprout and the bacteria will spread out from the diseased potato into the vessels of the young shoot and sooner or later cause it to wilt. Experiments performed here show that both of these alternatives are actually to be met with. Certain badly diseased potatoes were sown in pots. As no signs of sprouting were to be seen even after several weeks, the potato seed was dug up and was found to have become quite rotten. The potatoes used in the above experiment were, as stated, badly diseased and showed, on being cut across, the brown ring very distinctly indeed. The question at once arose, *Is it possible that tubers harvested from a plot where the disease has been present can contain the germs of the disease even although they show no brown ring?* In order to answer this question potatoes harvested from a plot in the Laboratory compound where the disease had been present the previous season were chosen. These, as is the custom, were kept three months before planting. Only cut seed was used and all seed that showed even a suspicion of a brown ring was thrown away. The seed was, therefore, as far as the eye could detect, quite healthy. The plot (C) on which these potatoes were planted had not, at least for the last ten years, been planted with potatoes and probably never had, so that there could be no question of the disease having been already present in the soil. Notwithstanding this fact, the disease showed itself very soon after the young plants had come up, and was well scattered throughout the whole plot. By the time of harvest, out of a total of 668 plants that had come up 302 plants or almost half had died as a result of the wilt.

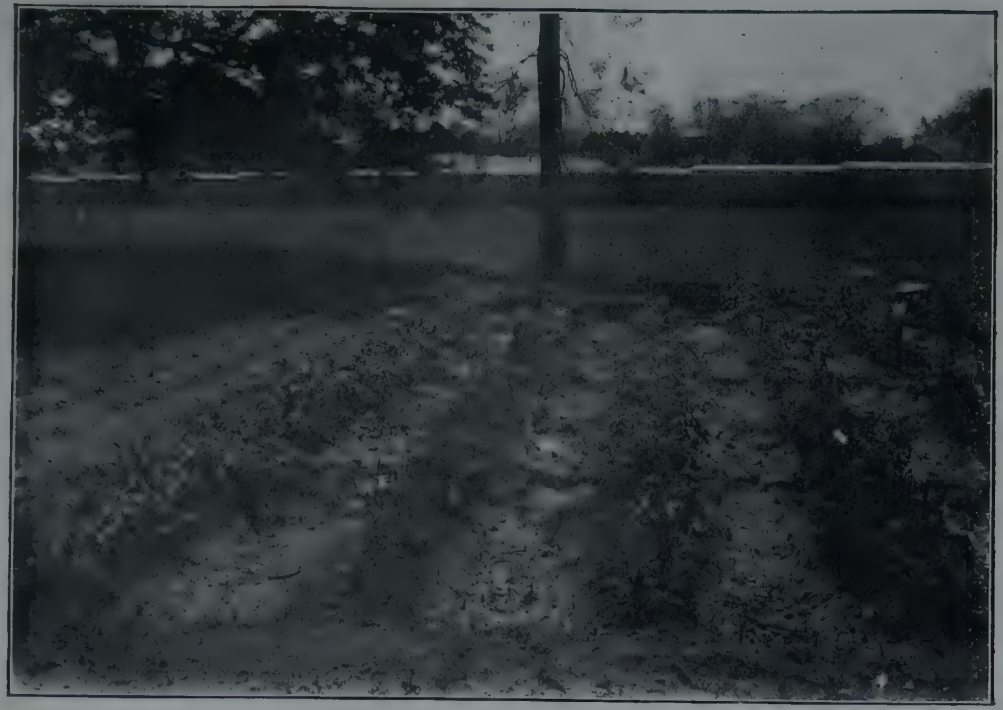

Fig. VIII.

Part of plot C, planted with seed from a plot where disease was present. The second row is badly wilted.

Fig. IX.

Young potato plant attached to set. It has begun to wilt (see lower leaves on right side). The brown ring is to be seen on the freshly cut surface of the set.

It is quite probable that many of these had been infected secondarily by means of bacteria which had spread from the diseased sets out through the soil. The irrigation water would facilitate such a spread. The accompanying Fig. VIII favors the view that a secondary spread actually took place. In the second row on the left in the figure it will be seen that very many of the plants have died from the wilt, whereas potatoes in the rows on either side have not done so to any appreciable extent. It seems highly probable that one or two sets in this affected row carried the germs of the disease and that from these the disease has spread along the rows through the soil. Many of the wilted plants on this plot, however, were dug up and examined under the microscope, for the presence of the bacteria, and in every such case it was found that the seed now showed the brown ring and large numbers of bacteria in the vessels. The disease had evidently been present in these seed potatoes all the time but had not been visible to the naked eye. After planting, the bacteria causing the disease had begun to grow again in the tubers and had spread out into the new shoots formed. (See Fig. IX.)

Another possible source of infection is the presence of these bacteria in the soil of the plot where the potatoes are planted. We will suppose a certain plot has been attacked by this disease. As a result a greater or less number of the potatoes have rotted in the ground and have, as a result, not been harvested. From these rotten potatoes the bacteria are able to spread out into the ground. If they are able to live in the ground till the next season for planting and if potatoes are planted on the same plot again, it seems quite possible that these bacteria should be able to gain an entrance into the new plants either through the seed (especially where simply cuts or eyes have been used in planting) or through the finer roots.

To test this point a plot A in the Laboratory compound on which a diseased crop of potatoes had been grown was planted out again the following season to potatoes with carefully selected seed obtained from a part where the disease was said not to be present. Separated from this plot by a path six feet wide was planted another

plot B, with just the same seed, but this time on soil on which no potatoes had previously been grown. On plot A by the time of harvest out of a total of 288 plants present at the beginning 229 had been killed by this disease leaving only 59 fairly healthy plants. On plot B the disease did not appear on a single plant showing that the seed was quite healthy. The accompanying three illustrations (Figs. X—XII) taken shortly before the harvest show clearly the difference between the two plots. Many of the diseased plants from these plots were also dug up and examined. It was found here that the sets showed no brown ring and practically never any bacteria in their vessels showing that the bacteria had not gained an entrance through the cut surface of the set. Fig. XIII shows two plants from this plot both growing from the same set. Both have begun to wilt and in the plant to the right the lower leaves show this quite clearly. The set cut through shows no sign of a brown ring. It was found, however, that in some of the roots and in the base of the stem bacteria were to be found in large numbers in the vessels. This would appear to indicate that the roots are the place through which the bacteria make their entrance from the soil. But how do they gain their entrance? Although it is not impossible that they may be able to bore their way into the roots themselves it seems hardly probable. It was found very frequently that small worms commonly known as eel-worms had made their way into some of the roots as well as into the tubers and the base of the stem. It seems quite possible that they may make an entrance for the bacteria. This question is at present being further investigated.

From the above experiment it is quite clear that these bacteria can remain alive in the soil from one potato season to another even when the land is allowed to dry out as is, of course, customary. There has not been sufficient time as yet to determine just how long the bacteria can remain alive in the soil. Experiments are still being conducted in that direction.

Are there still other means of spreading this disease? In this connection I may say that a similar, if not identical, disease is found attacking the potato in America. Dr. Erwin F. Smith of the Agricultural Department,

Fig. X.

Plots A and B. A is in the foreground and on it almost all the potato plants have died on account of infection from the soil. B, in the back ground, although planted with the same seed shows no sign of the disease

Fig. XI.

Plot A. Photo taken shortly before the harvest. Each stake with white ticket attached marks a plant that has died from the disease and the date upon which it wilted.

Fig. XII.

Plot B. Photo taken shortly before harvest. The plants are quite healthy and show no signs of wilt.

Fig. XIII.

Two young potato plants from plot A. The one to the right shows the wilt quite distinctly in the hanging down of the lower leaves. The set from which they have grown has been cut in two and the cut surface shown on the right shows no sign of the brown ring.

Washington has studied it thoroughly and has come to the conclusion that insects have a great deal to do with the spread of the disease. How this is possible can be indicated as follows:—

Many insects, especially small beetles, feed on the leaves of the potato. They are especially numerous in America. If one of these insects gnaws the leaf of a diseased plant it will in all likelihood get a large number of these bacteria on its jaws. If it then goes to a healthy plant, when it bites into the tissue it may carry some of these bacteria into the inside. Thus one can very easily see how insects could be very important agents in the spread of the disease.

In all my experiments I have kept a very careful watch for any instance of the spread of the disease by insects. There are a number of insects which have from time to time attacked the plants on my experimental plots. Among these are the potato moth, a small ladybird beetle *Epilachna*, several kinds of grasshoppers and one or two species of bugs. On the whole, however, insect attack has been insignificant, and although I have encountered very many wilted plants indeed I have never yet seen one in which the infection could, with any likelihood, be traced to the gnawing of insects. The results on plots A and B also speak strongly against the spread of the disease by means of insects. If insects were at all responsible for the spread of the disease they would almost certainly have carried it across the six-foot path separating plot A from plot B. In order to test the question still further, however, the following experiment was conducted. Inside a large field-cage for insects were put two pots. One of these contained potato plants which had been infected by pure cultures of the bacteria producing the disease and at the time they were put into the cage they were quite badly wilted. The other pot contained healthy plants. Into this cage were also introduced as many of the various different species of insects to be found feeding on the potatoes in the Experimental plots as could be conveniently gathered. The insects fed freely on both healthy and diseased plants. But although the experiment was carried on for several weeks the healthy plants did not contract the disease.

As far as conditions existing in Mysore are concerned we may, therefore, say with considerable assurance, that the appearance of the ring disease on a certain potato plot indicates either that the disease is present in the soil or that the seed used was more or less diseased. The fact that the seed shows no brown ring is no guarantee that it is not diseased. The results mentioned above on plot C clearly show this to be the case. Although the greatest care was taken to discard sets showing any sign of the brown ring, still the disease appeared.

Before discussing means of checking the disease it remains to be seen if it attacks any plants other than the potato. Two plants quite closely related to the potato are cultivated more or less extensively in this State. These are the tomato and the brinjal. It is a well-known fact with regard to plant diseases that closely related plants are frequently attacked by one and the same disease. In this connection Dr. Erwin F. Smith of the United States Department of Agriculture, has found, in the case of the above-mentioned potato disease, that it also attacks egg-plants (brinjals) and tomatoes. Experiments are at present under way to ascertain whether tomatoes and brinjals can be given the disease and the results already obtained show that both these plants can be infected with it by means of inoculation with pure growths of bacteria or with bacteria taken direct from diseased potato-tubers. Comparatively young plants practically always contract the disease after such an inoculation, whereas older plants seem to be able to resist it more or less successfully. In one successful experiment with tomato plants, eight comparatively young plants (hardly yet in the flowering stage) were inoculated with pure growths of the bacteria; all the eight contracted the disease and within three weeks were practically dead. Three larger plants (already bearing fruit) inoculated at the same time with the same growths of bacteria remained practically unaffected and could not after three weeks be distinguished from an uninoculated plant of the same age. Similar results have been obtained with brinjal plants. Young brinjal plants were inoculated with bacteria taken directly from diseased potato-tubers. These, almost without exception, took

A. B.

Fig. XIV.

Young brinjal plants of the same age. The plant in pot A has been inoculated with potato bacteria taken from diseased potato tuber. The plant in pot B has been left uninoculated.

Fig. XV.

Young brinjal plant showing an early stage of wilt as a result of inoculation ith bacteria taken from a diseased potato tuber.

the disease, whereas larger plants resisted it. The accompanying illustration (Fig. XIV) shows two young brinjal plants. The wilted plant was inoculated by means of needle-pricks with bacteria taken directly from a potato-tuber showing the brown ring. The healthy plant was not inoculated and is shown for comparison. In Fig. XV another brinjal plant similarly inoculated is shown. A microscopic examination of diseased plants was, of course, made, and the vessels were found plugged with bacteria just as in the case of diseased potato plants.

Both tomatoes and brinjals were also set out on plot A, which, as stated above, is badly infected with the bacteria. Although only a few plants could be set out, a number of both have wilted and died, and some of these have on microscopic examination shown the typical stoppages of the vessels by means of bacteria.

The results of these experiments leave no room for doubt but that this disease can be carried over on to both these plants. Whether such an infection does actually take place in Mysore in cases where potatoes, tomatoes and brinjals are grown in close proximity or one after the other on the same plot of ground, I am not at present able to state. In any case, the above experiments make quite clear the necessity of great care being taken to prevent any such cross infection.

How can the ring disease be best combated?

From the results obtained above we can clearly see that the following directions should be strictly adhered to, if possible :—

(1) Only such potatoes should be used as seed as have been grown on a plot which has been quite free from the disease. As pointed out already, it is not enough simply to discard all potatoes showing signs of the diseased ring. Any tubers grown on a plot where the disease has been present must be considered as possibly containing germs of the disease.

(2) As an additional precaution, where the seed is cut before planting, all pieces that have the least trace of brown spots or a brown ring should be discarded.

(3) If the disease has been prevalent on a certain piece of ground, potatoes should not be again planted there for at least one year. Probably two years would be better, but a definite statement in this connection cannot be made till the experiments in progress have been completed. Brinjals and tomatoes should also not be planted on such infected ground.

(4) Spraying the plants with a fungicidal or insecticidal spray is a waste of both time and money as the disease is not transmitted at least to any appreciable extent, by insects; nor can it be carried through the air from plant to plant. This, I may state, has been shown to be true by spraying experiments actually conducted here, but which have not been mentioned above.

(5) Another and a very effective means of checking the disease would be by the introduction of a disease-resistant variety of potato. In this connection it may be stated that experiments in this direction are in progress in co-operation with the Economic Botanist. A number of varieties of potatoes have been introduced by the writer from America and others have been introduced from England by the Economic Botanist. These varieties will, as the space on our Experimental plots permits, be tested as to their disease resistance. Such experiments will have to extend over more than one season as the experience of the past indicates that introduced varieties, although they may seem more resistant against the disease at first, tend to lose their power of resistance after some years' cultivation. In any case it is almost certain that many of these varieties will prove very much superior to those at present grown in Mysore, and it will be made quite certain that before they are distributed they are entirely free from the ring disease, so that with the observation of the precautions above mentioned they should be able to be

grown for many years in a disease-free condition. This will, of course, necessitate great care on the part of the potato growers themselves with regard to following the above directions.

In conclusion, it should be again pointed out that this is simply a popular description of the disease. Scientific terms have been avoided as far as possible. Later on, it is intended to publish a much more extensive and scientific paper on the same subject, in which will be incorporated the information that is being collected by this office with regard to potato-growing and potato diseases in Mysore as well as the results of experiments now in progress.